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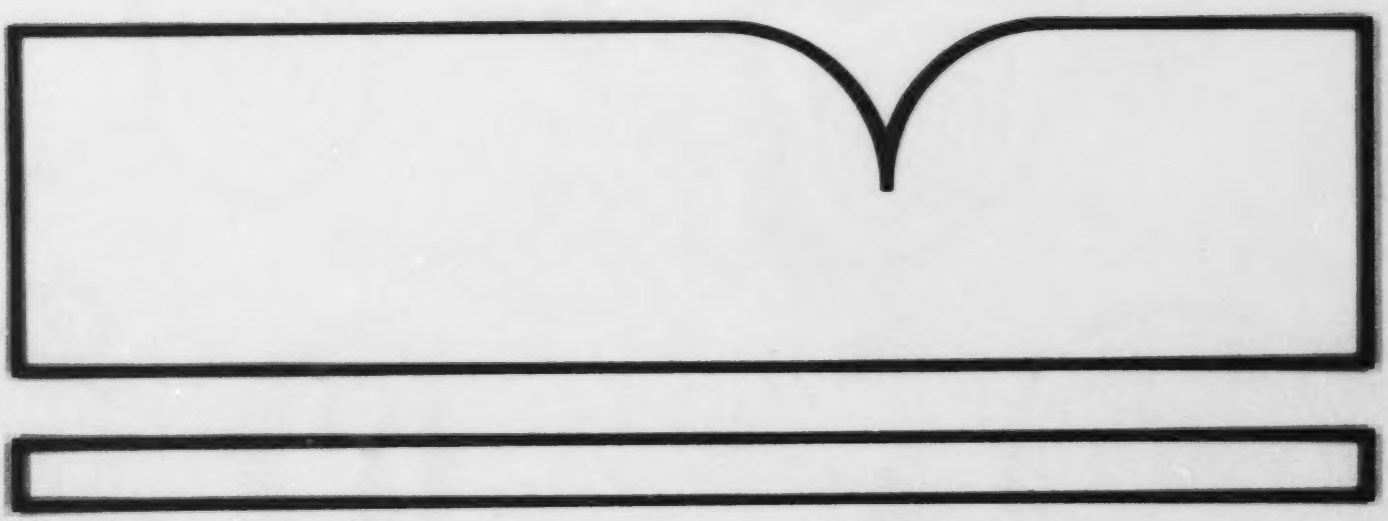

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RESULTS OF AIR SAMPLING FROM SELECTED ASBESTOS ABATEMENT PROJECTS

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16. ABSTRACT

The results of asbestos abatement monitoring at nine sites are discussed, comparing transmission electron microscopy analyses of post-abatement indoor levels with outdoor levels and comparing the t-test, z-test, and Wilcoxon test for clearance.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

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SUMMARY:

EPA has taken air samples following asbestos abatement at nine sites. Some of the samples were taken in conjunction with the samples used for the purpose of clearance and contractor release. Other samples at different buildings were taken after the buildings were occupied following abatement. Both 0.4-um pore size polycarbonate and 0.8-um pore size mixed cellulose ester filters were used to collect air samples whose volumes ranged from about 800 to 6000 liters of air. Asbestos analyses were by transmission electron microscope (TEM). In instances where abated areas were not occupied aggressive samples were taken.

All of the nine abatement sites were cleared by meeting the contractual airborne fiber concentrations as determined by PCM analyses. This was usually 0.01 f/cc. It is important to emphasize that the abatements were designed for PCM clearance rather than TEM clearance. Only one of the nine sites would have passed the EPA-recommended z-test when TEM analyses results were used.

INTRODUCTION:

The research reported in this paper was undertaken to evaluate the relative results of the various methods being used to measure airborne asbestos fibers in buildings following abatement. Other research[1] has indicated that in a short period of time airborne asbestos fibers settle or are attracted to surfaces by static charges, with the smaller fibers usually remaining airborne longest. About 99% of the airborne asbestos fibers observed in the nine site studies were too small to be seen by PCM. This observation emphasizes the need to require TEM for analysis, both to positively identify the fibers and to accurately measure the number and size.

Problems still persist in obtaining accurate, reliable samples and analyses. We recognize that contamination of filter blanks, variations in cassette loading and handling conditions, sample rate and total volume sampled, static deposition of fibers on cowls, preparation of samples for TEM analysis, and variations in microscopists' selection of grid openings for asbestos structure counting all can make final asbestos concentration results vary considerably. These variables are the factors which make it necessary to take enough samples to obtain a statistically reliable value on which to base the decision to clear abatement areas to be occupied.

The post-abatement cleaning of a site to remove enough residual surface deposits of asbestos and airborne asbestos fibers to meet clearance criteria the first time is the goal of every abatement contractor. To test this, at least five aggressive indoor samples must be statistically equal to or lower than concurrent outside sample concentrations by TEM analyses. Contractors accustomed to post-abatement clearance by PCM find that aggressive TEM clearance requires better cleaning or costly multiple re-cleaning.

SITES MONITORED:

The first site sampled was the EPA Environmental Research Center in Corvallis, Oregon. A sprayed-on approximately 80%-amosite material about 1/2- to 3/4-inch thick had been removed from ceilings in four rooms on the first floor of the building. The contractor cleaned, sampled, and cleared the areas by PCM. Subsequently, building maintenance personnel recleaned the areas, and in some cases painted the rooms. The areas had been re-occupied for several months with ongoing routine cleaning before we obtained both static and aggressive samples. The static samples were obtained on a Friday normal workday and the aggressive samples were taken the following day when the HVAC system was shut down. Since the HVAC system at Corvallis is a one-pass process, we anticipated low levels. The results surprisingly indicate the presence of residual asbestos even after several cleanings as shown on Tables 1 and 2. The TEM clearance test results for all sites are shown on Table 1. Table 2 shows data on all structures 3:1 aspect ratio.

Site 2 was the same USEPA Corvallis Environmental Research Center. This Phase II of abatement included removal of all remaining ACM, most of it in the penthouse, where the ceiling and beams were covered with the 80%-amosite ACM. Our monitoring on this phase took place within a few weeks after the completion of abatement. Large amounts of air (4000 to 6000 liters) were drawn through the nuclepore and millipore filters which were paired in unique dual mounts described by their developer, Carl Miller, in another paper to be presented at this conference. Both filters were available for TEM analysis. The asbestos concentrations are very low; however, the site fails the statistical tests.

Sites 3 thru 6 were glove bag removal jobs in the Cincinnati Public School system and were monitored by the National Institute of Occupational Safety and Health (NIOSH), working in a joint study with our Laboratory. Site 3 was Bloom School in Cincinnati; Site 4, Sands School; Site 5, Washburn School; and Site 6, Winton School. All were monitored during and after removal of asbestos-containing pipe insulation. Glove bags were used, but only after instructions were given by NIOSH Industrial Hygienists monitoring the work were the techniques improved sufficiently to resemble those envisioned by the authors of EPA guidance.[2] Their observations are, in part, the subject of NIOSH's Bruce Holletts' paper in session 12. The results from the glove bag monitoring studies are cause for concern of the use of glove bags. A well-intentioned but less-than-desirable glove bag job can easily contaminate an area. It is important to recognize that glove-bag removals still require the same containment and meticulous cleaning as would a full-scale removal job.

Site 7 was the Phase I removal of spray-on 30 to 60%-chrysotile ACM at Columbus East High School in Columbus, Indiana. This is a large three story complex of semi-open modern design. Removal was accomplished in three phases during summer vacation times.

Site 8 was the same Columbus East School during Phase II removal. The results shown are based on analyses of millipore mixed cellulose ester filters by TEM using a slightly modified NIOSH 7402 method. Phase II post-abatement TEM levels were significantly lower than Phase I levels, indicating improved removal and cleaning protocols. Still, however, neither of the phases would have passed TEM clearance.

Site 9 was a single story, multi-room elementary school whose authorities did not wish it to be identified. The abatement consisted of removal of chrysotile-loaded acoustic plaster on the ceiling with replacement by a non-asbestos sprayed-on insulation. Our inspection and monitoring was conducted after the replacement spray-back was finished and the area was rough-cleaned. Earlier inspections implied that the techniques used in this abatement would be less-desirable than those at the other sites. There was still debris apparent on window sills and in corners. Despite the appearance of contamination, very little asbestos was found in the TEM analyses and the area passed all of the TEM clearance criteria.

EPA has recommended that the asbestos structure concentrations in post-abatement air samples should be statistically no higher than ambient at the time of clearance where ambient would be the air entering the abated area. Several statistical methods were examined and compared in an effort to determine which most closely characterized the distributions and variance of the samples. The "z-test" is recommended in the "Silver Book"[3] entitled "Measuring Airborne Asbestos Following an Abatement Action". The "t-test" and the "Wilcoxon" tests were also examined. The calculations for these tests are shown on Figures 1 thru 3.

After consideration of all of these comparison tests, EPA has proposed in the "Asbestos-Containing Materials in Schools; Proposed Rule and Model Accreditation Plan; Rule"[4] a somewhat simplified clearance criteria. The proposed Rule 40 CFR Part 763 was published in the Federal Register Thursday April 30, 1987 and subsequently modified. The proposed rule will establish 70 asbestos structures per square millimeter of filter area as a clearance criteria as follows:

The proposed rule will provide two mechanisms for clearance:

1. If sufficient volumes of air are drawn (specified in the revised rule), the site may be released if the average of the asbestos structure count on the filters is less than 70 structures /sq mm. The revised rule now will call for the sample volumes to be a minimum of 1200 liters for a 25-mm dia filter and 2800 liters for a 37-mm dia filter for the 70-fibers/sq mm clearance criteria to apply.

2. If the average structure count exceeds 70 asbestos structures/sq mm, analyze three blanks to determine if the filters are contaminated.

3. If less than the specified air volumes are used or if the average structure count on the filters exceeds 70 fibers/sq mm and the blanks are OK, then a z-test must be conducted comparing the indoor and outside asbestos structure concentrations using at least five indoor and five outside samples.

The general conclusion derived from analysis of the test results examined is that a successful abatement consists of a complete treatment of the asbestos-containing material and a more detailed cleaning than most buildings have ever undergone in their lifetime. The results presented show that most buildings cleared by PCM will not pass the new 70 asbestos structures per square millimeter by TEM analysis proposed rule or the "z-test", and will require more meticulous cleaning to do so.

REFERENCES:

1. Environemtal Release of Asbestos From Commercial Product Shaping, EPA/600/S2-851044, August 1985

2. Guidance for Controlling Asbestos-Containing Materials in Buildings (Purple Book), EPA/560/5-85-024, June 1985

3. Measuring Airborne Asbestos Following an Abatement Action (Silver Book), EPA/600/4-85-049, November 1985

4. Proposed Rules: Part III Environmental Protection Agency, 40 CFR Part 763 Asbestos-Containing Materials in Schools; Proposed Rule and Model Accreditation Plan; Rule, Federal Register, Vol 52, No.83, Thursday, April 30, 1987

TABLE 1. SUMMARY OF CLEARANCE RESULTS

DATA FROM USEPA WATER ENGINEERING RESEARCH LABORATORY SEPTEMBER 3, 1987

SITE	NAME	70 STRUCTURE / SQ MM		T-TEST		Z-TEST		WILCOXON	
		All	AR>5, >0.5um	All	AR>5, >0.5um	All	AR>5, >0.5um	All	AR>5, >0.5um
1	CORVALLIS I	N/A	N/A	FAIL	FAIL	FAIL	FAIL	FAIL	PASS
2	CORVALLIS II	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
3	BLOOM SCHOOL	N/A	N/A	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
4	SANDS SCHOOL	N/A	N/A	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
5	WASHBURN SCHOOL	N/A	N/A	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
6	WINTON SCHOOL	N/A	N/A	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
7	COLUMBUS EAST I	N/A	N/A	FAIL	PASS	FAIL	FAIL	FAIL	PASS
8	COLUMBUS EAST II	N/A	N/A	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
9	OTS/ORD SITE I	N/A	N/A	PASS	PASS	PASS	PASS	PASS	PASS

NOTE: ALL MEANS ALL IDENTIFIED ASBESTOS STRUCTURES COUNTED (MOST HAD GREATER THAN 3:1 ASPECT RATIO)
AR>5, >0.5um MEANS ONLY ASBESTOS STRUCTURES WITH >5:1 ASPECT RATIO AND LONGER THAN 0.5 MICRONS ARE COUNTED

TABLE 2. ASBESTOS POST-ABATEMENT CLEARANCE RESULTS

DATA FROM USEPA WATER ENGINEERING RESEARCH LABORATORY SEPTEMBER 11,1987

LOCATION	ASBESTOS LEVELS			RELEASE DECISION
	Geometric Means (structures/cc)		Max. Indoor Value (structures/cc)	t-Test and z-Test
	Outdoor	Indoor		
CORVALLIS PHASE I	0.008	0.04	0.103	FAIL
CORVALLIS PHASE II	0.003	0.036	0.06	FAIL
BLOOM SCHOOL	0.006	0.314	0.571	FAIL
SANDS SCHOOL	0.001	0.102	0.312	FAIL
WASHBURN SCHOOL	0.002	0.212	0.528	FAIL
WINTON SCHOOL	0.002	0.065	0.167	FAIL
COLUMBUS EAST PHASE I	0.033	0.217	1.237	FAIL
COLUMBUS EAST PHASE II (MILLIPORE)	0.007	0.053	1.518	FAIL
OTS/ORD SITE I (MILLIPORE)	0.008	0.011	0.068	PASS

CALCULATION OF Z-TEST WORKSHEET

Inside Work Site ID No. _____

Outside Work Site ID No. _____

n_i = number of inside samples = _____

n_o = number of outside samples = _____

	INSIDE SAMPLES (f/cc)	LN INSIDE SAMPLES	OUTSIDE SAMPLES (f/cc)	LN OUTSIDE SAMPLES
(1)	ln (_____) =	_____	ln (_____) =	_____
(2)	ln (_____) =	_____	ln (_____) =	_____
(3)	ln (_____) =	_____	ln (_____) =	_____
(4)	ln (_____) =	_____	ln (_____) =	_____
(5)	ln (_____) =	_____	ln (_____) =	_____
	Total =	_____	Total =	_____
	$\bar{Y}_i$ = Total ÷ n_i =	_____	$\bar{Y}_o$ = Total ÷ n_o =	_____

(a) $\bar{Y}_i - \bar{Y}_o$ = _____

(b) $\frac{1}{n_i} + \frac{1}{n_o}$ = _____ , $\sqrt{\frac{1}{n_i} + \frac{1}{n_o}}$ = _____

(c) $0.8 \times \sqrt{\frac{1}{n_i} + \frac{1}{n_o}}$ = _____

$$z = \frac{\bar{Y}_i - \bar{Y}_o}{0.8\sqrt{\frac{1}{n_i} + \frac{1}{n_o}}} = (a) \div (c) = _____$$

Conclusion: _____ Work site fails if $z > 1.65$

_____ Work site passes if $z < 1.65$

Figure 1

5.3.3 Comparing Measured Levels of Airborne Asbestos

The appropriate statistical test for comparing levels of asbestos measured at the work site with those measured outside is known as the "difference between means" using Student's "t" test:

- Compute the natural logarithm of fiber concentration for each sample.
- Compute means of the log-transformed data for inside samples and for outside samples.
- Form the ratio:

$$t = \frac{\bar{Y}_i - \bar{Y}_o}{S\sqrt{\left(\frac{1}{n_i} + \frac{1}{n_o}\right)}}$$

Where:

$\bar{Y}_i$ = the average of log concentrations inside the work site

$\bar{Y}_o$ = the average of log concentrations outside the work site

$S = \{[\Sigma(Y_{ij} - \bar{Y}_i)^2 + \Sigma(Y_{oj} - \bar{Y}_o)^2] / (n_i + n_o - 2)\}^{1/2}$

n_i = number of samples inside the work site

n_o = number of samples outside the work site

- Then compare t to 1.86 if 10 samples were collected (the 95 percentile point of a "t" distribution with 8 $[n_i + n_o - 2]$ degrees of freedom). If t exceeds 1.86, the work site fails the test (consult a statistics text for the appropriate t value if the degrees of freedom are other than 8).

The fiber level data is log-transformed because frequency distributions of asbestos levels usually are highly skewed. The transformed data are adequately approximated by a normal distribution on which standard statistical methods can be used.

Figure 2

14.2 THE MANN-WHITNEY (WILCOXON) W TEST FOR TWO SAMPLES

If the two samples are not paired as in Section 14.1 and, in fact, if the samples are not necessarily the same size, we may proceed as follows. Suppose $(x_1, \ldots, x_m)$ and $(x'_1, \ldots, x'_n)$ are independent samples from populations having continuous c.d.f.'s $F_1(x)$ and $F_2(x)$ respectively. Let the two samples be pooled together into a single sample of $m + n$ observations and let the order statistics of this sample be $y_{(1)}, y_{(2)}, \ldots, y_{(m+n)}$. Consider the ranks (subscripts) of all y's which represent the elements of $(x_1, \ldots, x_m)$. Let the *sum of these* ranks be T, and let W be a random variable defined in terms of T as follows:

$$W = mn + \frac{m(m+1)}{2} - T. \tag{14.2.1}$$

Actually, W is the number of the mn possible pairs (x_i, x'_j) for which $x_i < x'_j$. W is the Mann-Whitney statistic, and T is the Wilcoxon statistic.

It can be shown by rather complicated analysis (which we omit) that, if the hypothesis H_0: $F_1(x) \equiv F_2(x)$ is true, that is, if both samples come from populations having identical c.d.f.'s, then for m and n both larger than 8, W has for all practical purposes approximately a normal distribution with mean

$$E(W) = \frac{mn}{2} \tag{14.2.2}$$

and variance

$$\text{Var}\,(W) = \frac{mn(m+n+1)}{12}. \tag{14.2.3}$$

As a matter of fact as m and n both approach infinity, the random variable

$$\frac{W - mn/2}{\sqrt{[mn(m+n+1)]/12}} \tag{14.2.4}$$

has as its limiting distribution the normal distribution $N(0, 1)$.

Example 14.2(a). Two chemists, A and B, make 14 and 16 determinations of plutonium, respectively, with the results shown in Table 14.2.1. (Numbers in parentheses are the rank of the observation in the combined sample.) The problem is to determine whether the two chemists are obtaining significantly different results.

Figure 3